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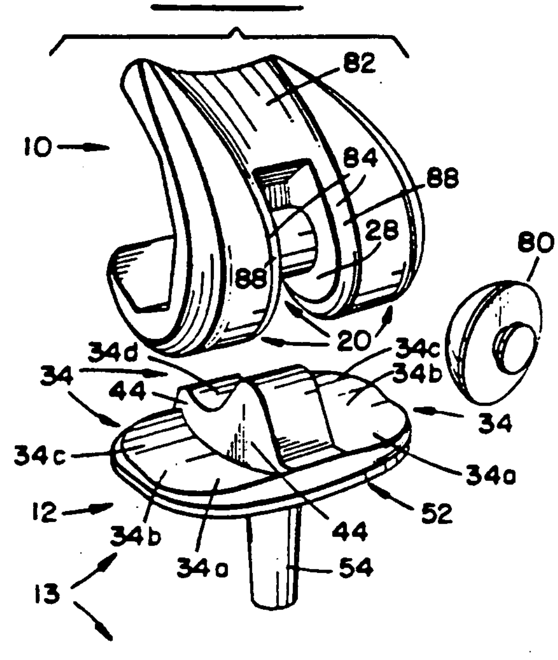
(54) Prosthetic joint.

(57) A prosthetic knee joint (10,12,13) is provided having an extended position (Figure 7), an intermediate position (Figure 8), and a flexed position (Figures 9 and 10). The motion of the joint includes a minor segment from the extended position to the intermediate position, and a major segment from the intermediate position to the flexed position. The center of pressure between the femoral component (10) and the tibial component (12) moves rearward on the tibia during the minor segment. During the major segment, the joint flexes about an axis of rotation (common center of radii R_3 and R_4) with the bearing surfaces (20c,20d,34c,34d) on the femoral (10) and tibial (12) components being in congruent engagement. The distal surface of the femoral component (10) includes two rails (88) for engagement with a patellar prosthesis (80).

FIG. I.



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This invention relates to improved prosthetic joints and in particular to improved prosthetic knee joints.

Flexion and extension of the normal human knee involves complex movements of three bones: the femur, the tibia, and the patella. During flexion, the distal end of the femur and the proximal end of the tibia rotate and glide relative to one another, with the center of rotation of the joint moving posteriorly over the condyles of the femur; during extension, the tibia and femur follow the reverse path, with the center of rotation now moving anteriorly as the joint is extended. Simultaneous with these movements of the femur and tibia, the patella moves over the surface of the femoral condyles, while remaining at a relatively constant distance from the tubercle of the tibia through the attachment of the patella to the tibia by the patellar ligament.

Numerous prostheses have been proposed as replacements for the natural knee joint. See, for example, Noiles, U.S. Patents Nos. 3,996,624, 4,219,893, and 4,301,553, Averill, U.S. Patents Nos. 3,728,742 and 4,217,666, Insall, U.S. Patent No. 4,213,209, Tavernetti, U.S. Pat. No. 3,813,700, German Patent Publications Nos. 2,227,090 and 2,501,128, and French Patent Publications Nos. 2,269,324 and 2,478,462. For total knee replacements, the condyles of the femur and the head of the tibia are surgically removed and replaced with prosthesis components. A patellar prosthesis, e.g., a spherically-domed or conical plastic button, is normally attached to the posterior surface of the patella to serve as an interface between the patella bone and the femoral prosthesis.

Efforts have been made to produce prosthetic joints which function in a manner similar to the natural knee. Specifically, a number of mechanisms have been proposed for producing posterior movement of the femoral component relative to the tibial component (femoral roll-back on the tibia) as the joint is flexed. For example, Walker et al., U.S. Pat. No. 4,209,861, discloses a prosthetic knee joint wherein guiding surfaces on the femoral and tibial components are used to induce posterior movement on the tibial component of the contact area between the components as the knee is progressively flexed. The posterior movement takes place through a major portion of the flexion of the joint. Burstein et al., U.S. Pat. No. 4,298,992, shows an alternate construction in which the femoral component moves posteriorly relative to the tibial component at or near full flexion. See also Deane, U.S. Pat. No. 3,840,905.

These prior art constructions suffer the common disadvantage that the femoral and tibial bearing surfaces are only in contact over small areas. Moreover, the contact areas become even smaller when the joint is flexed. During flexion, e.g., during such activities as squatting, stair climbing, or rising from a chair, high loads are applied to the joint and must be carried by the contact area between the bearing surfaces. Small contact areas plus high loads lead to high rates of wear of the bearing surfaces, which is clearly undesirable. U.S. Patent No. 4,634,444 to Douglas G. Noiles discloses a knee joint having bearing surfaces of large areas. However, the femoral component of this joint does not move posteriorly relative to the tibial component during flexion, as occurs in the natural knee.

Efforts have also been made to improve the functioning of patellar prostheses. See, for example Pappas et al., U.S. Pat. No. 4,470,158, Buechel et al., U.S. Pat. No. 4,309,778, and Buechel et al., U.S. Pat. No. 4,340,978. In particular, the anterior surfaces of femoral components have been provided with concave recesses for receiving patellar prostheses when the joint is at or near its fully extended position. See, for example, Forte et al., U.S. Pat. No. 4,353,135, and Walker, U.S. Pat. No. 4,209,861. Similarly, the distal surfaces of femoral components have included tracks for receiving the patellar prosthesis when the joint is flexed. Significantly, the surfaces which engage the patellar prosthesis on these prior art tracks have been convexly shaped. Indeed, discontinuities in the slope of the prosthesis' outer surface have existed at the intersection between the concave recess of the anterior surface and the convex track of the distal surface.

Prostheses employing convex tracks have suffered a number of disadvantages. When used with the typical spherically-domed or conical patellar prosthesis, the track and the patellar prosthesis have only made point contact. As discussed above, prosthetic knee joints are subject to high loads when flexed, i.e., when the patellar prosthesis is in contact with the distal track. This combination of high loads and point contact has resulted in high wear rates for the patellar prosthesis. Indeed, for patellar prostheses consisting of a plastic bearing mounted on a metal backing plate, complete wear through of the bearing so as to cause the metal plate and the metal femoral component to grind against one another in situ, has been observed.

In addition to the point contact problem, the discontinuity in the outer surface of the femoral prosthesis at the intersection between the concave recess and the convex track has also contributed to wearing of the patellar prosthesis and has degraded the overall smooth operation of the prosthesis.

The Forte et al. patent referred to above discloses a construction for a patellar prosthesis which can achieve line contact with a convex track. This construction, however, employs a complex patellar button geometry which must be precisely aligned

with the femoral prosthesis during the surgical procedure for the system to operate properly. Also, in revision surgery, the existing patellar prosthesis is normally not replaced. Most existing patellar prostheses are of the conical or spherically-domed button type. The Forte et al construction, like the rest of the prior art constructions, only provides point contact when used with such spherically-domed or conical patellar prostheses.

According to the present invention there is provided a prosthetic joint for providing flexion motion between two bones comprising:

(a) a convex bearing component having a first bearing area and a contiguous second bearing area, the second bearing area being a surface of revolution about a first axis and having a radius of curvature which is less than the radius of curvature of the first bearing area; and

(b) a concave bearing component having a third bearing area for engagement with the first bearing area and a contiguous fourth bearing area for engagement with the second bearing area, the fourth bearing area being a surface of revolution about a second axis and having a radius of curvature which is less than the radius of curvature of the third bearing area;

wherein:

the radius of curvature of the second bearing area is substantially the same as the radius of curvature of the fourth bearing area so that the second and fourth bearing areas may be in congruent engagement with one another; and

the flexion axis of the joint is parallel to the first and second axes when the second and fourth bearing areas are in engagement.

Preferably, the area of contact between the convex and concave bearing components is greater when the second and fourth bearing areas are in engagement than when the first and third bearing areas are in engagement.

Further preferably, the radius of curvature of the third bearing area is greater than the radius of curvature of the first bearing area.

The accompanying drawings, which are incorporated in and constitute part of the specification, illustrate the preferred embodiments of the invention, and together with the description, serve to explain the principles of the invention. It is to be understood, of course, that both the drawings and the description are explanatory only and are not restrictive of the invention. In particular, it is to be understood that although, for ease of discussion, the description which appears below is in terms of an artificial knee joint, various aspects of the invention are equally applicable to other types of artificial joints, such as, artificial elbow joints and the like.

Figure 1 is a perspective, exploded view of a semi-constrained artificial knee joint constructed in accordance with the present invention.

Figure 2 is a side view of the tibial plateau component of the joint of Figure 1.

Figure 3 is a view of the anterior surface of the femoral component of the joint of Figure 1 showing the engagement of the patellar component of the joint of Figure 1 with the anterior surface.

Figure 4 is a view of the anterior surface of the femoral component of the joint of Figure 1 showing the engagement of the patellar component with the distal surface of the femoral component.

Figure 5 is a view of the distal surface of the femoral component of the joint of Figure 1 showing the engagement of the patellar component with the anterior surface.

Figure 6 is a cross-sectional view along lines 6-6 in Figure 4.

Figures 7-10 are side views of the joint of Figure 1 at flexion angles of 0°, 16°, 45°, and 120°, respectively.

Figure 11 is a side view of the joint of Figure 1 at a hyperextended angle of -6°.

Figures 12 and 13 compare the engagement between the patellar and femoral components achieved with the present invention (Figure 13) with that achieved with prior art prostheses (Figure 12).

Figure 14 is a perspective, exploded view of a constrained artificial knee joint employing the patella tracking system of the present invention.

Figure 15 is a cross-sectional view of the joint of Figure 14 along the midline of she prosthesis.

Figure 16 is a side view of the femoral and patellar components of the Joint of Figure 14.

Figure 17 is a view of the distal surface of the femoral component of the Joint of Figure 14 showing the engagement of the patellar component with the distal surface.

Figure 18 is a perspective view of a patellar prosthesis having a saddle-shaped surface.

Figures 19 and 20 are sectional views in sagittal planes comparing the engagement of the femoral component of the joint of Figure 14 with a spherically-domed patellar button (Figure 20) and with the patellar prosthesis of Figure 18 (Figure 19).

Referring now to the figures, there is shown in Figure 1 an exploded view of a semi-constrained artificial knee joint constructed in accordance with the present invention. The joint includes a femoral component 10 and a tibial component 13 comprising tibial plateau component 12 and tibial sleeve component 14. As discussed in detail below, the joint is designed to smoothly interact with patellar

prosthesis 80.

Femoral component 10 and tibial plateau component 12 respectively carry mating convex bearing surface 20 and concave bearing surface 34 (see Figure 1). As shown in Figure 6, femoral convex bearing surface 20 is composed of part 20a described by radius R_1, part 20b described by radius R_2, and part 20c described by radius R_3. Femoral convex surface 20 also includes part 20d described by radius R_4. Radius R_4 has the same center as radius R_3, and therefore surface 20d is concentric with surface 20c. Part 20b is also referred to herein as the first portion of convex bearing surface 20; the combination of parts 20c and 20d are also referred to herein as the second portion of convex bearing surface 20.

As shown in Figure 2, tibial concave bearing surface 34 is composed of part 34a described by radius R_1, part 34b which may be flat or concave with a radius greater than radius R_2 of femoral component 10, and part 34c described by radius R_3. Tibial concave surface 34 also includes part 34d described by radius R_4. Radius R_4 has the same center as radius R_3, and therefore surface 34d is concentric with surface 34c. Part 34b is also referred to herein as the first portion of concave bearing surface 34; the combination of parts 34c and 34d are also referred to herein as the second portion of concave bearing surface 34.

As shown in Figures 1 and 5, each of parts 20a, 20b, and 20c, and parts 34a, 34b, and 34c are composed of two spaced-apart sections. The spaced-apart sections of parts 20c and 34c, in combination with parts 20d and 34d, respectively, form stepped bearings of the type disclosed in U.S. Patent No. 4,634,444, referred to above. As shown in the figures, these stepped bearings extend across the full width of the prosthesis so as to provide a large, wear-resistant bearing surface for flexion motions of the joint. Preferably, parts 20c and 20d, i.e., the second portion of convex bearing surface 20, and parts 34c and 34d, i.e., the second portion of concave bearing surface 34, are surfaces of revolution, i.e., cylindrical in shape, although other bearing contours can be used in the practice of the invention.

So that the bearing surfaces can come apart in a direction orthogonal to their axis of rotation, the second portion of concave bearing surface 34 encompasses less than one-half of the second portion of convex bearing surface 20. In particular, as shown in Figure 9, the second portions engage each other over an angle A, which for the embodiment shown is approximately 15°.

The spaced-apart sections of part 34c are connected to part 34d by walls 44. Similarly, the spaced-apart section of part 20c are connected to part 20d by walls 28. The presence of these walls stabilizes the assembled joint against dislocations along the axis of rotation of the second portions of bearings 20 and 34. Specifically, the engagement of the walls limits the lateral motion of surfaces 20 and 34 with respect to one another. Significantly, this stabilization is achieved without sacrificing the overall width of the bearing surfaces, as would occur with other modes of lateral stabilization known in the art, such as, through the use of a post or the like between two laterally separated bearing surfaces.

As shown in the figures, the outer sections of parts 20c and 34c have equal radii of curvature, and those radii of curvature are larger than the radius of curvature of parts 20d and 34d. It is to be understood that the bearing surfaces can have radii of curvature other than those shown, provided that the radii are such that their differences produce walls 28 and 44 of sufficient height to restrain the joint against lateral dislocations.

As can best be seen in Figure 2, in addition to bearing surfaces 34, tibial plateau component 12 also includes cam means 41. Similarly, as can be seen in Figure 6, femoral component 10 includes cam means 43. Cam means 41 is located between the spaced-apart sections of part 34b and comprises an extension of part 34d. Cam means 43 is located between the spaced-apart sections of part 20b and comprises an extension of part 20d. Cam means 41 is connected to part 34b by extensions of walls 44. Similarly, cam means 43 is connected to part 20b by extensions of walls 28. These extensions can also engage against one another to help restrain the joint at flexion angles against lateral dislocations.

The operation of cam means 41 and 43 is illustrated in Figures 7-10, where Figure 7 shows the joint in its extended position, Figure 8 shows the joint in its intermediate position, and Figures 9 and 10 show the Joint at flexion angles of 45° and 120°, respectively.

As shown in these figures, parts 20b and 34b, i.e., the first portions of surfaces 20 and 34, are in engagement in the joint's extended position (Figure 7) and roll relative to one another as the joint moves from its extended position to its intermediate position (Figure 8). The theoretical contact between parts 20b and 34b during this rolling is line contact. Cam means 41 and 43 interact during this portion of the joint's motion to allow and control the rolling between the bearing surfaces. The natural forces in the knee tend to keep the cam means in contact through the minor segment of the Joint's motion.

Parts 20c and 34c, as well as parts 20d and 34d, come into engagement at the intermediate position and remain in engagement throughout the remainder of the flexion of the joint (Figures 9-10).

The motion of the joint when these second portions of surfaces 20 and 34 are in engagement consists of simple rotation of the joint about the axis defined by the common center of radii R_3 and R_4. The second portions slide on one another during this rotation.

The transition from the engagement of the first portions, which, as discussed above, is theoretically just line contact, to the engagement of the second portions results in an increase in the contact area between the bearing surfaces. Specifically, the contact area increases because of the congruent meshing of part 20c with part 34c and part 20d with part 34d. Flexing beyond the intermediate position is accomplished with substantial bearing areas in contact to resist the high femur to tibia loads created by weight bearing at greater flexion angles. For the joint of Figure 1, this congruent bearing area is on the order of 1.0 square inch.

To maximize the contact area between the bearing surfaces through the major segment of the motion of the joint, the transition between the first and second portions of the bearing surfaces is performed early in the flexion of the joint. In Figures 7-10, the transition takes place at a flexion angle of about 16° from the extended position of the joint. The motion of the joint thus consists of a minor segment from 0° to about 16°, and a major segment from about 16° to the flexed position of the joint, e.g., 100° to 120°, with the major segment being about 5 times greater than the minor segment.

The transition point between the first and second portions of the bearing surfaces can of course be set at flexion angles either greater than or less than 16°. In general, the transition point should occur at a flexion angle of less than about 30° in order to obtain the full benefits of the enhanced bearing surface contact area provided by the engagement of the second portions.

In addition to moving between its extended and flexed positions, the joint of Figure 1 can also be hyperextended. The amount of hyperextension permitted is determined by the engagement of surface 72 on femoral component 10 (see Figure 6) with surface 70 on tibial plateau 12 (see Figure 2). Radius R_1 of femoral surface 20a also comes into contact with radius R_1 of tibial surface 34a which further inhibits hyperextension. Figure 11 shows the joint in its fully hyperextended condition. For the joint shown, the hyperextension is limited to -6°. Greater or lesser amounts of hyperextension can be permitted as desired.

In addition to carrying convex bearing surface 20 and cam means 43, femoral component 10 also includes fixation shank 16 which is adapted to be implanted in the patient's femur using standard surgical techniques. Similarly, in addition to concave bearing surface 34 and cam means 41, tibial plateau component 12 also includes depending shaft 54 and thrust bearing surface 52. As shown in Figure 2, depending shaft 54 can optionally include metal reinforcing rod 74.

In the assembled joint, bearing surface 52 on the bottom of tibial plateau component 12 mates with bearing surface 58, i.e., the top surface of tibial sleeve 14, and depending shaft 54 is received in aperture 56 formed in the body of the tibial sleeve. As fully described in U.S. Patents 4,219,893 and 4,301,553, referred to above, the pertinent portions of which are incorporated herein by reference, this arrangement of these components allows tibial sleeve 14 to rotate with respect to tibial plateau component 12 as the femur and tibia move from a position of full extension to a position of flexion. This rotation of the tibia about its longitudinal axis during flexion - is normally in the range of 10-15°.

Tibial sleeve component 14 is designed to be implanted in the upper portion of the tibia. Various approaches can be employed for this implantation. One such approach is that described in PCT Patent Publication No. WO85/03426, entitled "Apparatus for Affixing a Prosthesis to Bone," which is assigned to the same assignee as this application. Briefly, this technique involves providing tibial sleeve 14 with an outer surface 60 which has been contoured to mate with a portion of the inner surface of the hard bone at the upper end of the tibia. In addition to being anatomically contoured, the surface is also provided with a geometry 62 designed to transform wedging shear loading to compression loading in the tibial bone. A further discussion of the technique can be found in the above-referenced patent publication, the pertinent portions of which are incorporated herein by reference.

In addition to engaging tibial component 13, femoral component 10 also engages patellar prosthesis 80. For this purpose, the anterior surface of the femoral component includes concave recess 82 and the distal surface includes track 84 which intersects the recess. Track 84 is composed of rails 88, each of which has a cross-sectional contour in a direction transverse to the longitudinal axis of the rail which is 1) either a straight line or a concave curve, 2) constant along the length of the rail, and 3) matches the contour of the surface of recess 82 at the intersection between the rail and the recess.

The advantage of constructing rails 88 in accordance with the invention is illustrated in Figures 12 and 13. Figure 12 shows the construction used in the prior art wherein the portion of the distal surface of femoral prosthesis 92 which engaged patellar prosthesis 80 is convexly shaped. As

shown in this figure, the two prostheses only make point contact at points 90. Such point contact leads to high wear rates for the patellar prosthesis. Also, in such prior art prostheses, distinct slope changes exist at the intersection between the convex surface and the concave recess formed in the prosthesis' anterior surface for receiving the patellar prosthesis.

In contrast to Figure 12, as shown in Figure 13, when rails 88 are given the configuration of the present invention, line contact along curves 94 is achieved between the patellar and femoral prostheses. As shown in Figure 4, to achieve this line contact for a spherically-domed patellar button, curves 94 are portions of a circle having the same radius of curvature R_5 as the domed surface of the patellar prosthesis. For typical prosthesis dimensions, each of curves 94 can have a length, which corresponds to the width of the rail, on the order of 5-6 millimeters.

The line contact between the patellar prosthesis and the distal surface of the femoral prosthesis results in substantially reduced wear rates in comparison to those achieved with point contact. Also, as can be seen in, for example, Figure 1, the concave contour of rails 88 results in a completely smooth transition between the rails and concave recess 82.

In the case of a conical patellar button, rails 88 are portions of a straight line instead of being concave. In such a case, recess 82 would preferably be V-shaped, i.e., composed of two inwardly sloping planes, so as to produce a smooth transition between the rails and the recess.

A patellar prosthesis 96 for use with the present invention which achieves even greater contact with the distal surface of the femoral prosthesis is shown in Figure 18. The anterior surface of this prosthesis includes peg 98 for attaching the prosthesis to the posterior surface of the patient's patella. The posterior surface of the prosthesis, which engages the femoral prosthesis in the assembled joint, has a saddle shape.

As shown in Figure 18, the saddle has a radius of curvature R_5 in the medial-lateral direction. This curvature matches the medial-lateral radius of curvature of rails 88 (see Figures 4 and 13), and thus contact like that achieved for a spherically-domed patellar prosthesis is achieved in this direction. Along lines 100 and 102, the saddle has radii of curvature of R_2 and R_2', respectively. As can be seen in Figure 6, R_2 is the radius of curvature of the outer edge of rails 88, while R_2' is the radius of curvature of the inner edge of the rail. Accordingly, patellar prosthesis 96 will make surface contact throughout areas 104 with rails 88 of the femoral prosthesis when the patellar button is in contact with the R_2 section of track 84, which condition exists during the high contact forces created by flexion and weight bearing.

This enhanced contact is illustrated in the sectional views of Figures 19 and 20. As shown in Figure 20, through the use of concave rails 88, a spherically-domed button is able to achieve line contact along line 138. However, as shown in Figure 19, by using concave rails and a button having the saddle contour of Figure 18, contact is achieved throughout area 140.

Figures 14-20 illustrate a constrained ("hinged") artificial knee joint employing concave rails 88 for engaging either spherically-domed patellar prosthesis 80 or saddle-shaped patellar prosthesis 96. For this prosthesis, tibial plateau 12 carries hinge post 106. For this purpose, the tibial plateau includes slot 120 having side walls 122. The hinge post is mounted to the tibial plateau by snapping flanges 110 under beads 108 formed in side walls 122.

Hinge pest 106 includes hole 112 for receiving tic flanged bearings 114, one from each side. The joint is assembled by slipping femoral component 10 over the hinge post to bring bearing surfaces 130 on the femoral component into contact with bearing surfaces 132 on the tibial plateau. Hinge pin 116 is then slid through holes 126 in the femoral component and through bearings 114 to assemble the hinge. Hinge pin 116 is held in place by means of snap rings 118 which are received in grooves 128.

As in the joint of Figures 1-11, the joint of Figures 14-20 has large bearing surfaces which extend across essentially the full width of the joint. Specifically, the bearing surfaces associated with the femoral side of the Joint comprise surfaces 130 and lower outer surface 134 of hinge pin 116. The corresponding concentric bearings surfaces on the tibial side comprise surfaces 132 and the lower inner surface of bearings 114.

Hinge pin 116 and femoral component 10 are made from materials having similar wear characteristics, e.g., from titanium or cobalt chromium alloys. Similarly, bearings 114 and tibial plateau 12 are made from materials having similar wear characteristics, e.g., from ultra-high molecular weight polyethylene. In this way, the concentricity of the bearing surfaces is maintained as those surfaces wear since the wearable components, i.e., the plastic components, are all associated with one side of the joint, e.g., the tibial side, and are all surfaces of revolution about the same center line, while the non-wearable components, i.e., the metal components, are all associated with the other side of the joint, e.g., the femoral side, and are surfaces of revolution about the same center line as the plastic components. Accordingly, as the plastic components wear, the common Center line will simply

shift, e.g., move towards the tibia, with each of the metal and plastic bearing surfaces remaining concentric to its mating surface.

Bearing surfaces 130 are located further from the midplane of the joint than bearing surfaces typically used in hinged joints. This change allows rails 88 to be moved far enough apart to provide a stable engagement with the patellar prosthesis. During articulation of the joint, rails 88 ride inside of walls 122 and are received in slot 120. The outside surface of the femoral component 10 includes recesses 142 which engage protuberances 144 at the limit of the extension of the joint.

Femoral component 10, tibial component 13 and patellar components 80 and 96 can be made out of a variety of biologically compatible, surgically implantable materials. For example, a cobalt-chromium-molybdenum alloy, such as that described in ASTM F75, can be used for femoral component 10, a titanium-aluminum-vanadium alloy, such as that described in ASTM F136 can be used for tibial sleeve 14, and ultra-high molecular weight polyethylene (UHMWPE) can be used for tibial plateau component 12, bearings 114 and the patellar prostheses. Similarly, hinge post 106, hinge pin 116, and snap rings 118 can be made of cobalt-chrome or titanium alloys. Other types and combinations of materials appropriate for use in the artificial joint of the present invention will be evident to persons skilled in the art.

Although specific embodiments of the invention have been described and illustrated, it is to be understood that modifications can be made without departing from the invention's scope. For example, bearing surfaces have configurations other than those shown herein can be used in the practice of the invention. Similarly, a variety of can means other than those described can be used to permit rolling of the bearing surfaces relative to each other during the minor segment of the joint's motion.

Claims

1. A prosthetic joint for providing flexion motion between two bones comprising:

   (a) a convex bearing component (10) having a first bearing area (20b) and a contiguous second bearing area (20c), the second bearing area (20c) being a surface of revolution about a first axis and having a radius of curvature (R_3) which is less than the radius of curvature (R_2) off the first bearing area (20b); and

   (b) a concave bearing component (13) having a third bearing area (34b) for engagement with the first bearing area (20b) and a contiguous fourth baring area (34c) for engagement with the second bearing area (20c), the fourth bearing area (34c) being a surface of revolution about a second axis and having a radius of curvature (R_3) which is less than the radius of curvature of the third bearing area (34b);

   wherein:

   the radius of curvature (R_3) of the second bearing area (20c) is substantially the same as the radius of curvature (R_3) of the fourth bearing area (34c) so that the second and fourth bearing areas (20c, 34c) may be in congruent engagement with one another; and

   the flexion axis of the joint is parallel to the first and second axes when the second and fourth bearing areas (20c, 34c) are in engagement.

2. The prosthetic joint of Claim 1 wherein the area of contact between the convex and concave bearing components (10, 13) is greater when the second and fourth bearing areas (20c, 34c) are in engagement the when the first and third bearing areas (20b, 34b) are in engagement.

3. The prosthetic joint of Claim 1 or 2 wherein the radius of curvature of the third bearing area (34b) is greater than the radius of curvature (R_2) of the first bearing area (20b).

4. The prosthetic joint of Claim 1, 2 or 3 wherein the joint is a knee joint, the first component (10) is a femoral component, and the second component (13) is a tibial component.

FIG. 1.

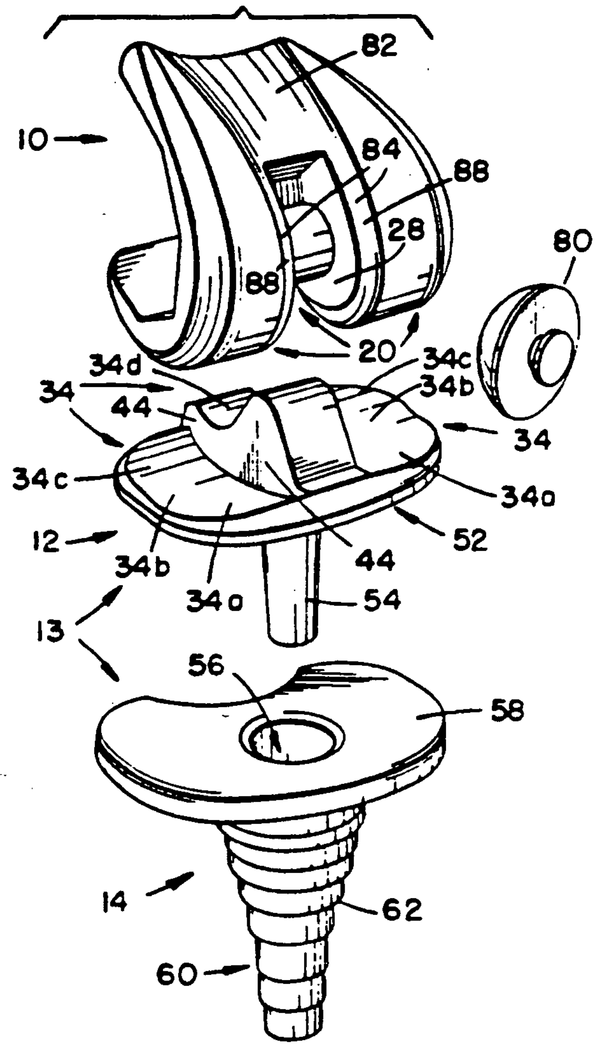

FIG. 2.

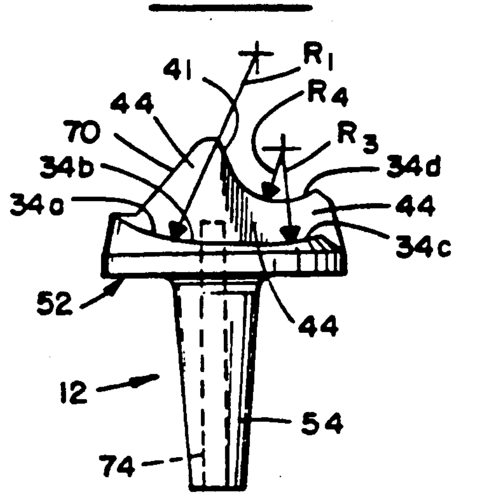

FIG. 3.

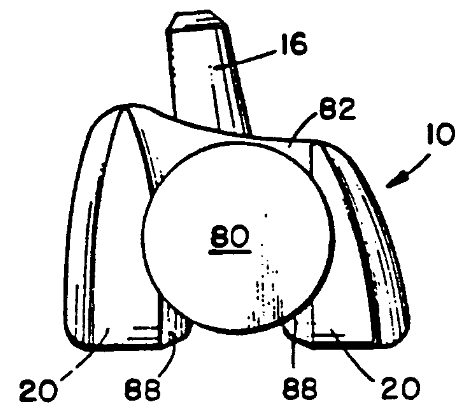

FIG. 4.

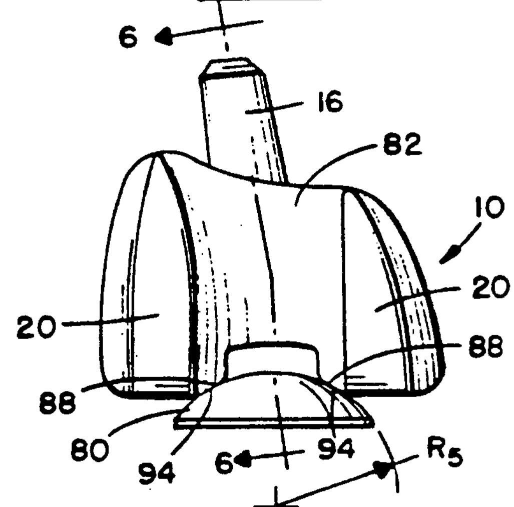

FIG. 5.

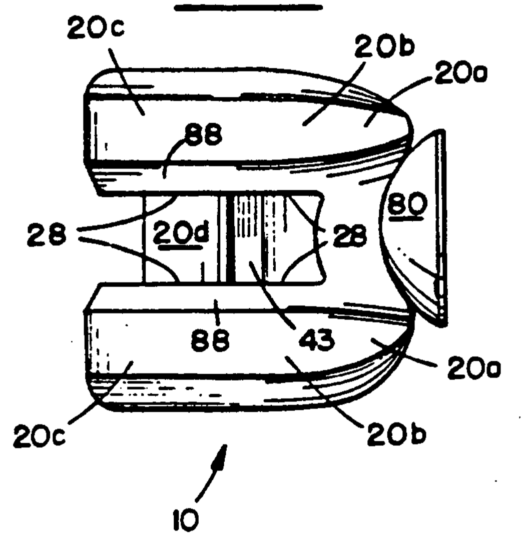

FIG. 6.

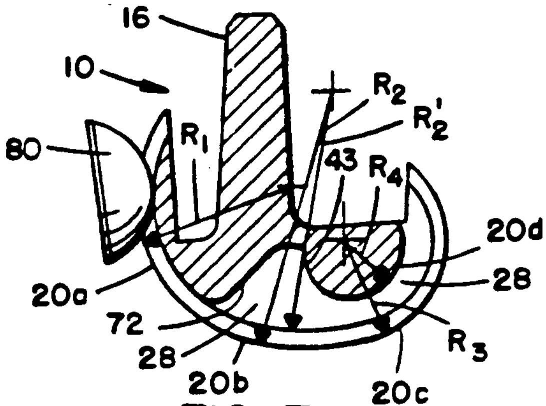

FIG. 7.

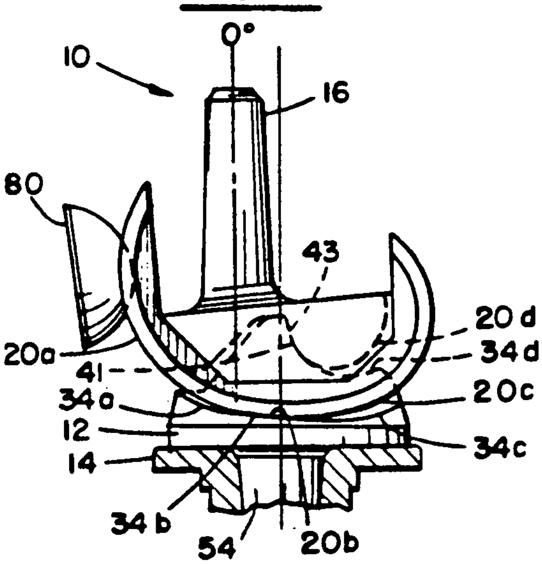

FIG. 10.

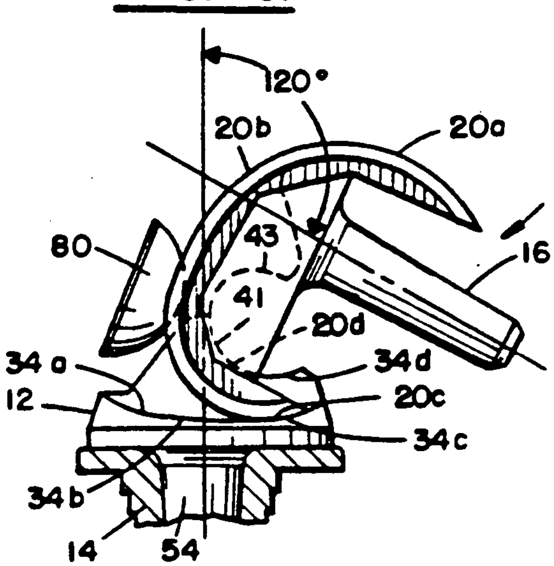

FIG. 11.

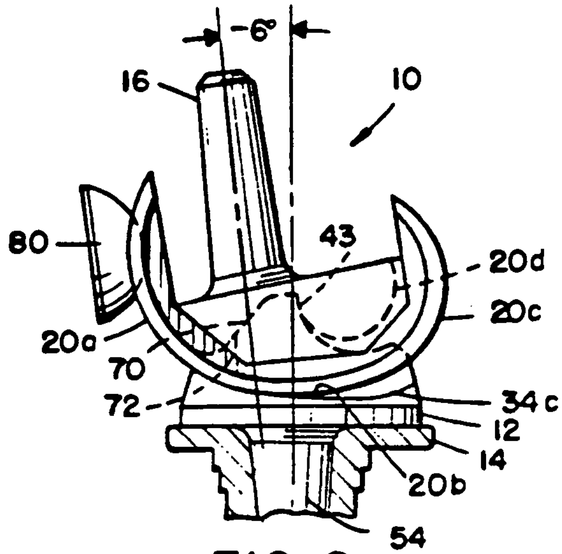

FIG. 9.

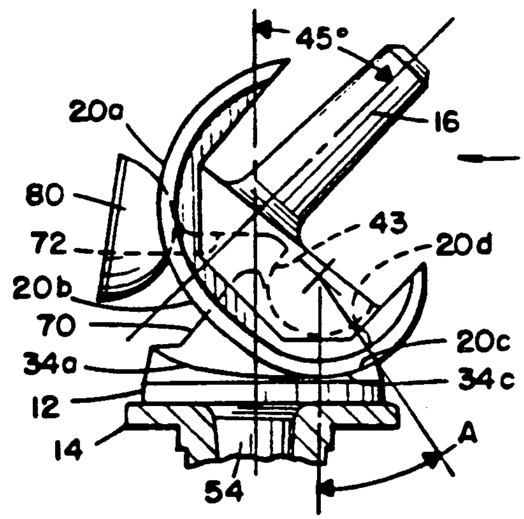

FIG. 8.

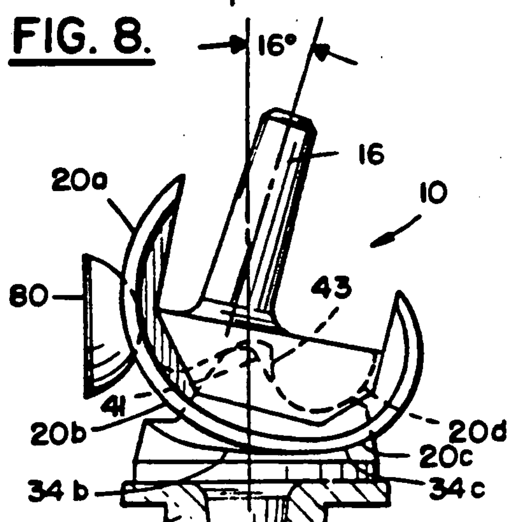

FIG. 14.

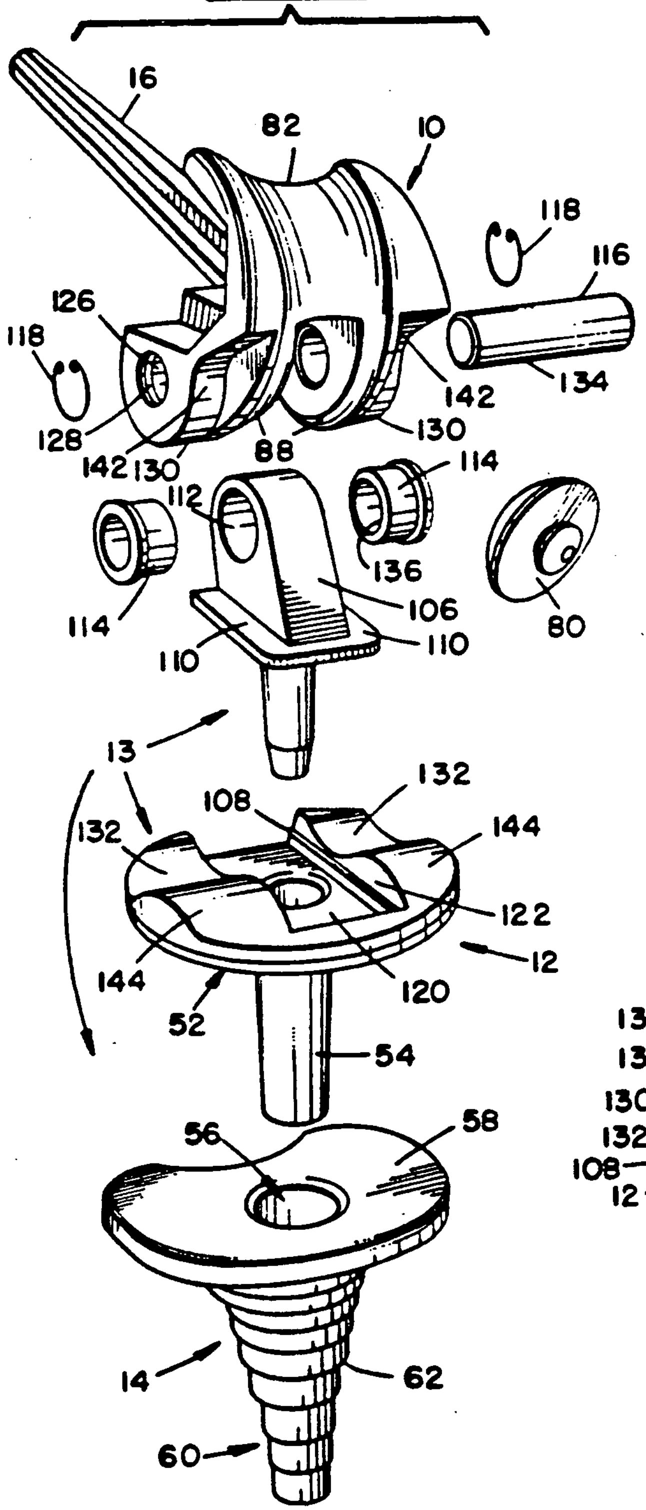

FIG. 12.

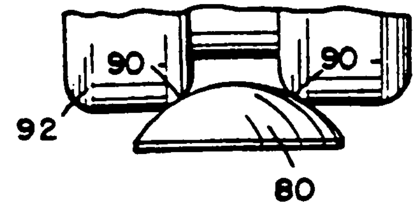

FIG. 13.

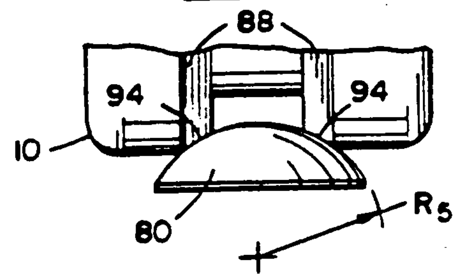

FIG. 15.

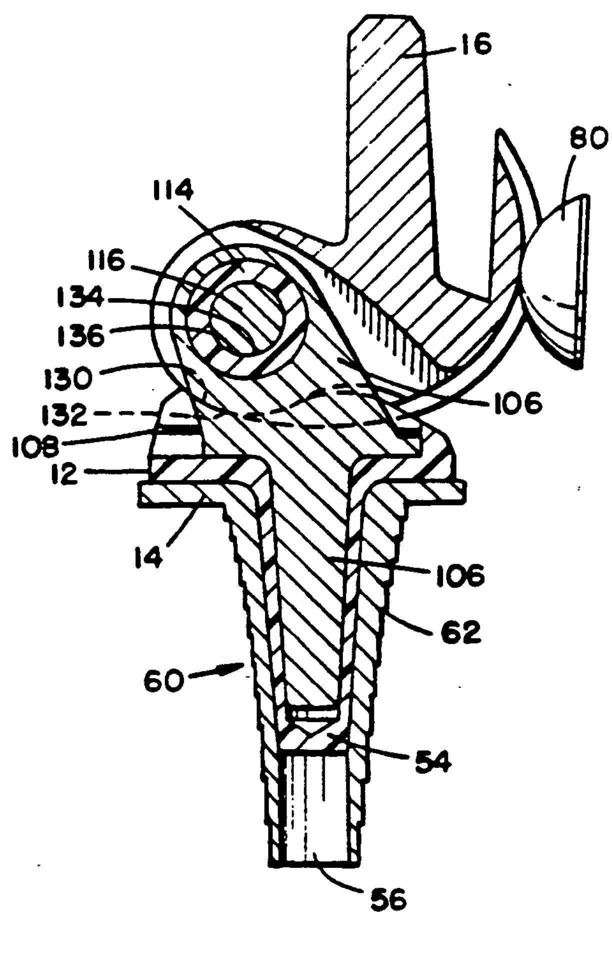

FIG. 16.

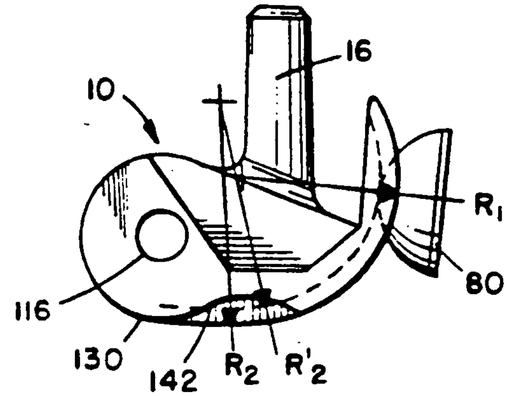

FIG. 17.

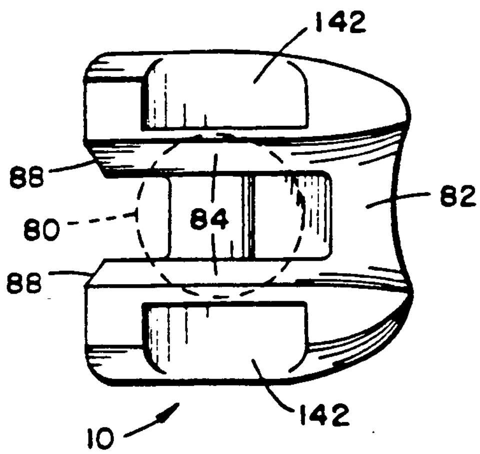

FIG. 18.

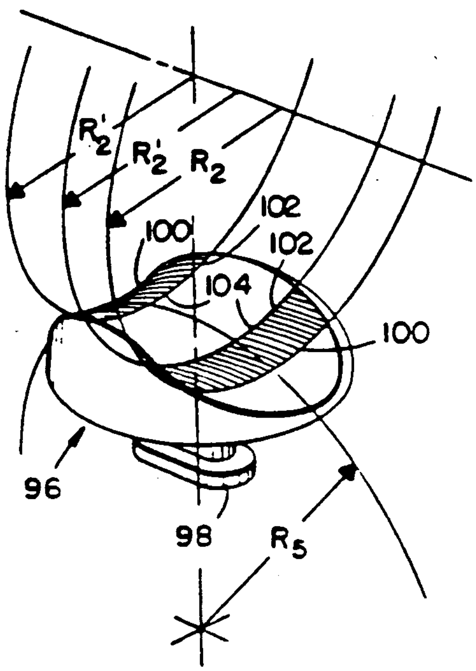

FIG. 19.

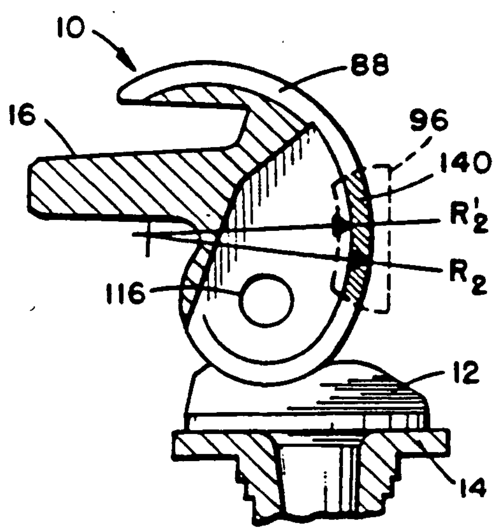

FIG. 20.